APPENDIX G

OVERVIEW OF THE LAKE MICHIGAN BASIN

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OVERVIEW OF THE LAKE MICHIGAN BASIN

This appendix describes the general setting and characteristics of the Lake Michigan basin, including the physical and biological history of the basin, key facts and figures about the region, Areas of Concern, and Areas of Stewardship. This appendix concludes with a description of key areas and habitat types in the basin.

G.1 HISTORICAL CONTEXT

In order to assess the status of the Lake Michigan ecosystem, the ecosystem must be viewed in its historical context. This section will describe the geology, climate, pre-settlement plants and animals, and a brief history of human settlement in the Lake Michigan basin.

G.1.1 Geology

The Lake Michigan basin is part of the Great Lakes basin, which was formed during the last 10,000 years. However, the foundation for the Great Lakes basin was laid over 3 billion years ago, during the Precambrian Era. The Precambrian Era was a long period of geologic activity. Mountain systems were built of sedimentary and volcanic rocks, which were then folded and heated and eroded. During the Paleozoic Era some 230 to 600 million years ago, the area was covered by marine seas that deposited lime silts, clays, sand, and salts; these substances consolidated into limestone, shale, halite, and gypsum.

More than 1 million years ago, during the Pleistocene Epoch, the first glacier moved over the Great Lakes region. With ice more than 6,500 feet thick, it scoured the earth and leveled hills. Valleys formed prior to the glacier were deepened and enlarged to form basins that would eventually become the Great Lakes. After thousands of years, the climate warmed and the glacier retreated, allowing vegetation and wildlife to return. This was repeated several times over thousands of years.

Glacial drift (sand, silt, clay and boulders) was deposited with each successive glacier. Resulting features seen today include moraines, linear mounds of fill material, flat till plains, drumlins, and eskers, all formed of well sorted sands and gravels. These areas are significant because they are groundwater storage and transmission areas (aquifers). They are also sources of commercial sand and gravel extraction.

As the glaciers retreated, large volumes of meltwater occurred along the front of the ice, forming large lakes. After the first glaciers, these lakes were larger than our present-day Great Lakes. The beach ridges along the perimeter of Lake Michigan (flat plains and eroded bluffs) indicate former lake shorelines.

As the last glacier retreated, the land began to rise. This “uplift” caused changes in the size, depth, and drainage patterns of the glacial lakes. Today, the water from Lake Michigan flows to Lake Huron through the Straits of Mackinac. The straits are deep and wide. As a result, both lakes are at the same elevation.

About 10,000 years ago, the present Great Lakes basin appeared. The “uplift” or crustal tilting, as it is called, is still occurring in Lakes Superior and Ontario. Crustal tilting, along with long-term weather pattern changes, suggests the Great Lakes are continuing to evolve *(Great Lakes: An Environmental Atlas and Resource Book* 1995).

G.1.2 Climate

Advancing and retreating glaciers carved out Lake Michigan and the Lake Michigan basin. Water levels changed in response to melting ice. The results of the glaciers can be seen along the varied shoreline and in the abandoned former lake shoreline inland. In the Indiana Dunes National Lakeshore at the southern end of the lake, for example, a series of dune ridges marks the progression of the lake's retreating water levels. The youngest dunes are found closest to the shore, formed between 4,000 years ago and present (Hill and others 1991).

Today, warm, moist air from the Pacific Ocean and the Gulf of Mexico collides with cold, dry arctic air over the Lake Michigan basin. Due to its sheer size and volume, the lake moderates the effects of both air systems by acting as a heat or cold "sink." As a result, shoreline temperatures differ from the temperatures of inland areas (Brown and others 1974). In the summer, temperatures near the shoreline are cooler than inland. This is reversed in the fall, with relatively warmer lake waters moderating the air temperature near the lakeshore. In addition to modifying temperatures in the basin, the lake influences weather patterns, precipitation, and wind velocity and direction (Eichenlaub 1979).

Global warming resulting from human activities poses the threat of increased temperatures and changing precipitation rates. The Lake Michigan shoreline could change quickly, submerging or exposing ecosystems accustomed to harshness and variability but unable to cope with rapid, permanent changes.

G.1.3 Plants and Animals

In the last ice age the spruce and fir forests that are today in northern Canada followed the retreating ice at about 1 kilometer per year. The climate was warming at a rate of 1 or 2 °C degrees every 1,000 years (Schneider 1989). As the ice retreated, new plant and animal species colonized and interacted, mostly from the surrounding watersheds which connected to the lake through channels, rivers and wetlands (Baily and Smith 1981).

The fish species that colonized Lake Michigan began to evolve in response to opportunities or niches present in the form of varying depths, embayments, and the corresponding food supplies and habitats afforded by geography. In particular, one fish family (the *Coregonids*) became very successful at filling these niches. This family includes the lake whitefish, lake herring, chubs, and ciscoes. Expansion of this fish family into different habitats within the lake resulted in the development of separate stocks, subspecies, and species, including the deepwater ciscoe known as *C. johannae,* which was endemic to Lake Michigan (Baily and Smith 1981).

Terrestrial plant and animal species colonized the Lake Michigan basin from other areas of the continent after each glacial retreat. As a result, the basin is a mixture of unique species from the boreal forests of the north, the grasslands of the west, and the deciduous forests of the east.

Ecoregions are large landscape areas defined by climate, physical characteristics, and the plants and animals that are able to live there. Defined ecoregions help to identify the unique plant and animal species and their habitats that colonized the Lake Michigan basin after the last glacier retreated some 8,000 to 10,000 years ago.

The Southern Lower Michigan Ecoregion extends across the southern half of the lower peninsula of Michigan. Before settlement, this region was forested with oak-hickory or beech-sugar maple mixtures. Closer to the lake and dunes were forests of eastern hemlock, beech, white pine, red and white oak, and sugar maple. Extensive marshes, fens, and swamp forests were also present. Oak hickory and lakeplain areas were dependent on fire to rejuvenate native plant communities. Today, the ecoregion is comprised

of rolling hills and flat lakeplains of fertile soils. The shoreline is banded with sand dunes. Sand dunes are threatened by mining; forests and lakeplain areas are being developed; and fire suppression has degraded oak-hickory forests and lakeplains.

The South Central Great Lakes Ecoregion overlaps with the Southern Lower Michigan Ecoregion. It extends from Muskegon, Michigan, through Northwest Indiana to the Calumet region on the southeast side of Chicago. Before settlement, the dune ridges closest to the lake were covered by white pine and jack pine. Further from the lake, the ridges were oak-hickory savannas, and in the lowlands, tallgrass prairies. Wetlands interspersed the dunes ridges. Near Warren Woods, Michigan, beech-maple forests blanketed the area. Today, this region is a combination of gently rolling lowlands, flat plains, and dune and swale ridges formed by receding glaciers. Industrial and urban development dominate the ecoregion; however, it is still surprisingly rich in biological diversity and protected areas.

The Southwestern Great Lakes Morainal Ecoregion and the overlapping Southeast Wisconsin Savanna Ecoregion extends from southeast Chicago to Milwaukee and inland to central Wisconsin. Before settlement, beaches and low, white pine and jack pine covered dunes, lakeplain prairies, and diverse wetlands were nearest the lake. Inland, lakeplain oak savanna and prairie communities and wetlands dominated the landscape. Today, the region is characterized by flat, undulating topography resulting from glaciation. The lakeshore is largely hardened with artificially nourished beaches and the most heavily urbanized development of the Lake Michigan basin. Small remnant natural areas are protected in a mosaic of parks and protected areas.

The Northern Lacustrine-Influenced Upper Michigan and Wisconsin Ecoregion extends north of Milwaukee and includes Door County and the areas to the Mackinac Bridge. Before settlement, the region was covered by northern hardwood forest, jack pine barrens, white and red pine forests, and hardwood and conifer swamps. Dune and swale topography characterized the nearshore with ridges of white or red pine, white spruce, balsam fir, and hardwoods. Extensive marshes were found along the shoreline, particularly in Green Bay. Fire was important in maintaining the jack pine barrens. Early post-settlement, intensive logging depleted forest resources, followed by agriculture. Today, the Lake Michigan shoreline is bedrock or cobble beach of exposed limestone and dolomite. Residential and vacation home development pressures are stressing the ecosystems along the shoreline.

The Northern Lacustrine-Influenced Lower Michigan Ecoregion extends across the upper half of Michigan's lower peninsula. Before European settlement, jack pine, white pine, and northern pin oak dominated large areas of this region. Today, limestone bedrock is exposed along the shore. Sand deposits are thick. Much of the area has been logged. Orchards and vineyards have replaced forests. Residential and vacation home developments are replacing natural ecosystems.

G.1.4 Human Habitation

The first inhabitants of the Lake Michigan basin arrived as the last glacier was receding about 10,000 years ago. When French explorer Jean Nicolet and the French voyagers began traveling through the basin beginning in the early 1600s, while searching for a passage to the Orient, the Lake Michigan basin was inhabited by the Illinois, Potowattomi, Fox, Menominee, and other Tribes dependent on the fur bearing and game animals of the region, as well as subsistence foods such as wild rice, and trees for canoes and shelter. In 1763 the region, including Lake Michigan, came under British control. When the United States acquired the Northwest Territory in 1796, the Lake Michigan basin was included. Explorers were succeeded by missionaries and fur trappers and finally, settlers. The Native Americans were relegated to reservations or moved further west.

Significant changes to the Lake Michigan ecosystem began in the mid-1800s, when large numbers of people began to settle the region. By 1850, commercial fishing was a major industry and had resulted in a noticeable decline in fish populations by the 1870s (Wells and McLain 1973, Eshenroder and others 1995). Industrial pollution had also begun to affect fish populations as the result of the damming of rivers, deforestation, and the dumping of sawmill and other waste into the tributaries and lake itself. The waterways became major highways for trade. The fertile land yielded lumber and agricultural products.

The earliest loggers harvested white pine. Stands of virgin white pine reached 60 meters in height, and a single tree could contain 10 cubic meters (6,000 board feet) of lumber. Because it is light and strong, the pine was much in demand for shipbuilding and construction. Other hardwoods such as maple, walnut, and oak were logged to make furniture, barrels, and specialty products. The logging industry was exploitive at this time. Clear cutting and improper reforestation practices denuded the landscape throughout the basin. Soils were eroded and streams and rivers choked with sediment. The water quality of streams, rivers, and lakes was degraded.

Large-scale clearing of the land for agriculture in the 1800s rapidly changed the landscape as well. Wheat and corn were the first commodities to be packed in barrels and shipped from the region. Grist mills, one of the region's first industries, were built on tributaries to process grains for shipment. Specialty crops such as fruits and vegetables were grown for a burgeoning urban population. Wetlands were filled to create more land for crops. Tributaries and streams were dammed and channelized, and flows were diverted to fields, leading to an imbalance in natural water level fluctuations. Soils stripped of natural vegetation for agricultural use washed away to the lake. Fish habitats and spawning areas were destroyed by surface runoff from poor agricultural practices.

The northern part of the basin was an important mining area. Dolomite and limestone, as well as marble granite and iron were mined in the Kingsford/Iron Mountain area on the Menominee River and near communities of Escanaba, Menominee, and Manistique.

By 1900 the population of the region soared. Chicago and Milwaukee were major cities and centers for Great Lakes trade and transportation of goods throughout the Midwest. Industrial development flourished. Further north, the paper production industry developed at Green Bay.

Commercial fishing greatly expanded until a significant change to the ecosystem occurred. Sea lamprey, which entered the upper Great Lakes when bypasses to Niagara Falls were constructed, were first noted in Lake Michigan in 1936. By the late 1940s, the sea lamprey had decimated the lake trout and burbot populations, the top predator fish. With the elimination of the top predators, two exotic species, the alewife and rainbow smelt, flourished. By the 1960s, the lake was dominated by the alewife and, to a lesser extent, rainbow smelt. The native fish community was severely disrupted, and important commercial and sport fisheries had collapsed. *Coregonid* populations were also affected and resulted in the extinction of several species of deepwater ciscoes, including *C. johannae*. Lake trout were extirpated and to this day are not self-sustaining in Lake Michigan (Koonce 1994).

G.2 FACTS AND FIGURES: LAKE MICHIGAN BASIN TODAY

Lake Michigan, the second largest of the Great Lakes by volume (1,180 cubic miles) and the third largest by surface area (22,300 square miles) is the only Great Lake entirely within the United States, in parts of Michigan, Indiana, Illinois, and Wisconsin. The lake is 307 miles from north to south and 118 miles at its widest from east to west. It averages 279 feet in depth, with a maximum depth of 925 feet. The water retention time is 99 years, which means it takes 99 years for water to cycle through the lake.

The length of the Lake Michigan shoreline is 1,638 miles. The total land drainage area of the watershed is 45,600 square miles. The northern part of the watershed is cooler and forested. The southern, more temperate portion of the basin is urbanized, heavily industrialized, and agriculturally productive.

G.2.1 Basin Population

More than 10,057,000 people live in the basin, primarily in the southern Lake Michigan, Chicago-Milwaukee metropolitan region. This figure includes the 2,914,250 people living in Cook County, Illinois, which is part of the original Lake Michigan basin boundary before implementation of the diversions to the Illinois River/Mississippi River drainage basin.

Within the original basin boundary, Illinois contains 3,494,115 people, or 34.7 percent of the Lake Michigan basin population with a land area of 93 square miles (0.03 percent). Post diversion this figure is reduced to 579,865 people or 8.1 percent. Although the water used within the diversion area is not discharged to the Lake Michigan basin, the water supply for that population comes directly from Lake Michigan and, for the purposes of this discussion, the population relates to the original Lake Michigan basin boundary.

Indiana has 604 square miles or 2.5 percent of the basin's land area and 10.8 percent (339,264) of the basin's population. When Indiana is combined with Illinois, only slightly more than 2.5 percent of the land area in the basin is home to nearly one of every two people or 45.5 percent of the entire basin population.

Wisconsin has 2,467,463 people (24.5 percent) in its part of the basin. Approximately 70 percent of Wisconsin's coastal population reside in four southeastern counties: Ozaukee, Milwaukee, Racine, and Kenosha. Over half of the state's coastal population resides in Milwaukee County alone. The population of the city of Milwaukee and neighboring Racine declined significantly from 1970 to 1990 (-11.3 percent and -9.9 percent, respectively). In contrast, the city of Green Bay had a stable population during the 1970s and experienced a significant 9.7 percent population increase from 1980 to 1990–a trend that has continued through the 1990s. Lake Michigan coastal populations in Wisconsin counties outside Milwaukee increased by 4.2 percent between 1980 and 1990, and by 5.3 percent between 1990 and 1995–higher than in three decades. However, trends indicate continued high rates of second-home development (40 percent to more than 80 percent in the northeast). Seasonal populations in coastal counties peak during summer months, when there is almost one visitor for every two permanent residents. In the winter months, the seasonal population is only about the state average for both periods.

Michigan has 3,007,954 people in its share of the basin, or 30 percent of the Lake Michigan basin population. Census population figures, based on the number of permanent residents in an area, do not reflect the seasonal aspects of a population. Seasonal populations–tourists and recreational visitors–can play an important role in characterizing certain areas in the Lake Michigan basin. A study of the 10-county area of the northeastern portion of the basin (northwest Michigan), for example, concluded that one person in six (about 16 percent) staying in the region in 1995 was not part of the permanent population. Forty percent of those were people staying in second homes. Data for the eastern basin indicate that second-home development is projected to slow somewhat between 1990 and 2010 compared with the previous 7 percent of the region. However, counties with smaller permanent populations that have winter ski resorts experience much higher percentage winter seasonal populations.

The most significant population trend for the Lake Michigan basin is a shift away from central cities coupled with rapid growth in the surrounding metropolitan areas. In some places, this outlying growth reflects an increase only in the number of households (a shift in population density due to declining household size), not in population; however, in other places, it is a true increase in population in the

outlying areas. In any case, this population shift to the urban periphery and suburbs together with the attendant trend towards smaller household sizes and demand for low-density development consumes vast amounts of agricultural lands and open space. It also alters the character of what were once small towns, distinct from urban areas, as these small towns are consumed by the ever-expanding metropolitan areas.

In basin metropolitan areas near the shore, the implications for the nearshore area are even greater because, on the one hand, the lake geographically limits how far people can move lakeward away from the city and, on the other hand, the lake provides a natural attraction for new development. The result is that many of the people leaving the central cities are heading for the nearshore area. The city of Chicago, for example, lost population between 1980 and 1990, whereas the Chicago metropolitan area experienced continued growth in areas outside the central city to the south, away from the lake, and north along the Lake Michigan shoreline. The Milwaukee/Racine area in Wisconsin, discussed above, is another example where population has increased at the county level.

Another trend is the remarkable population decrease in the highly urbanized areas in Northwest Indiana, which includes East Chicago, Hammond, and Gary. Between 1980 and 1990, the population in these cities declined by 14.8 percent, 10.1 percent, and 23.2 percent, respectively. This has been the trend since the 1970s and is expected to continue, although it has slowed somewhat in the 1990s. This population change has been influenced by the downsizing of steel mills and other manufacturing industries in the area. As the population declines in the tri-city area, more people move to the urban and suburban areas toward the southern watershed boundaries, as well as northward into Michigan along the Lake Michigan shoreline.

G.2.2 Water Use

Consumptive water uses–uses for which a quantity of water is withdrawn and not replenished–have minor impacts on the Lake Michigan water level. Lake Michigan is the source for drinking water for the communities near the lake. Millions of gallons are withdrawn daily to supply an estimated 100 gallons per person daily in the basin. Groundwater is the reservoir for supplying water to the lake via the basin's many tributaries (Manninen 1999).

Thermoelectric power plants, industry, agriculture and public water supply are other consumptive users of Lake Michigan water. For 1992, comprehensive water-use data for Wisconsin, Illinois, and Indiana (Michigan data was not available) indicate that about 90 percent (18,455 of 20,500 million gallons per day [mgd/day]) of the total water used in those parts of the Lake Michigan basin comes from surface water–both from Lake Michigan directly and its tributaries. The remaining water comes from groundwater sources.

The largest single use of withdrawn surface water for all Lake Michigan basin states is for cooling at thermoelectric power plants (more than 48 percent for Indiana, Illinois, and Wisconsin). This water comes directly from Lake Michigan. Approximately 10 percent of the surface water use in the Illinois, Indiana, and Wisconsin portion of the basin is for industrial purposes (for example, in steel and paper production). In fact, Indiana's concentration of heavy industry, particularly in its Lake Michigan counties, has made it the nation's largest industrial water-using state. Agricultural use for irrigation and livestock represents about 4.5 percent of total water use from all sources. Only about 7 percent of surface water use (1.369 Mgal/day) in the Indiana, Illinois, and Wisconsin portion of the basin is for public water supply, and about half for navigation, sanitation, and water quality purposes.

Lake Michigan water is diverted at Chicago to the Chicago Sanitary and Ship Canal. The canal links the lake to the Mississippi River. It is used as drinking water, for sewage disposal, and for commercial

navigation. This diversion is one of five in the Great Lakes and has been disputed and limited by order of the U.S. Supreme Court (Maninnen 1999).

Non-consumptive water uses–uses for which no water is consumed–include hydroelectric power, recreational boating and fishing, and shipping. The second largest water-use category in the Indiana, Illinois, and Wisconsin portion of the basin is hydroelectric power, which accounts for about 31 percent of total surface water use for the non-Michigan portion of the basin.

According to the 1991, United States national fishing and hunting survey, 34 percent of all Great Lakes anglers fished in Lake Michigan, a close second to Lake Erie's 35 percent. The number of recreational boats operated on Lake Michigan each year is estimated at 400,000, or nearly half the number for all the Great Lakes. Although boating has a strong connection to fishing, which relies on clean water and productive fish stocks, much of the boating activity is tied to marina and new nearshore residential development, which degrades nearshore habitat and water quality in localized areas. Along Indiana's Lake Michigan shoreline, for example, boat slips increased from 1,100 in 1985 to 2,700 in 1991, although many new marina developments in Indiana are occurring on previously developed sites.

Lake Michigan remains an important resource for waterborne navigation in and around every lakefront community and through many of its tributaries. The U.S. Congress has authorized a total of 51 federal navigation projects in Lake Michigan and its tributaries. The majority of commerce at Lake Michigan ports is internal in the Great Lakes–materials are transported from one Great Lake port to another. Raw materials associated with steel making (such as iron ore, limestone, and coal) dominate the overall tonnages of commercial cargo transported at Lake Michigan ports. Coal remains a common cargo at many of the smaller commercial harbors, largely for coal-fired power plants.

G.2.3 Land Use

The Lake Michigan basin land use profile varies considerably from north to south. Forested lands dominate the northern portion of the basin. Preliminary data collected in 1993 by the U.S. Forest Service indicate that each of the Lake Michigan-adjacent counties in Michigan's upper peninsula contains more than 202,500 hectares (500,000 acres) of forested land. Historically, the northern basin has also been an important mining area—primarily dolomite (limestone) with some marble, granite, and iron ore (Michigan State University 1977). The heavily forested north gradually gives way to predominately agricultural lands in both the eastern and western portions of the basin. In 1991 and 1992, 35.7 percent of the basin's land was farmland, most of which was cropland and pasture. The Door Peninsula in the western basin and the "fruit belt" along the coastal counties of the eastern basin are important areas for orchards and specialty crops. Southward, agricultural land is increasingly interspersed with urban areas. The extreme southern portion of the basin—a relatively narrow band of land adjacent to the lake–is heavily urbanized. Between 40 and 46 percent of the land in the Indiana-Illinois portion of the basin is classified as urban.

Although every Great Lakes basin has some sand dunes and beaches, the expanse of sand dunes and beaches along Lake Michigan's eastern shore is one of its most impressive features. This extent of sandy beach and dunes is accented by Sleeping Bear Dunes National Lakeshore in the north and the Indiana Dunes National Lakeshore in the south—the latter containing the third highest plant diversity of all U.S. national parks (U.S. Geological Survey 1991).

The greatest alteration of the Lake Michigan nearshore environment has been in the southern part of the basin where intensive urban and industrial development has resulted in filling and "hardening" of the shoreline and discharge of large amounts of pollutants into the air, water, and lands of that coastal region.

A ridge of sedimentary rock forms an arc in the middle of the Great Lakes basin and is the source of prominent natural features found in several of the Great Lake basins. In the Lake Michigan basin, this ridge is the source of the Door and Garden Peninsulas that separate Green Bay from Lake Michigan. Perhaps the most spectacular part of this ridge, known as the Niagara Escarpment, runs through the Lake Huron and Lake Erie basins in Ontario forming the Bruce Peninsula and Manitoulin Island in the north and extending south and to the east, where the waters of Lake Erie spill over it on their way to Lake Ontario, forming one of North America's most famous tourist attractions: Niagara Falls (Ashworth 1986).

The northern part of the Lake Michigan basin, including Green Bay and Michigan's Upper Peninsula, is dominated by the forestry industry and recreational land uses. This former mining region is today sparsely populated, with the majority of people living in Green Bay, Escanaba, Menominee, and Manistique. The northern basin serves as one of the nation's foremost Christmas tree growing regions, and the Fox River-Green Bay area of the Lake Michigan basin is recognized as the world's largest concentration of pulp and paper mills. Pulp and paper mills historically have contributed to significant pollution problems, but improvements over the last two decades have been substantial. Mill effluents containing dioxin and other chlorinated organic compounds which posed a threat to human health and the environment. New production and treatment technologies are reducing and, for particular facilities, eliminating these pollutants. Contamination from past practices, however, remains a significant concern.

Just west of Green Bay, the Menominee Indian Reservation is a showcase for sustainable forest practices. The Wolf River watershed is forested and relatively undeveloped; however, a mine in the upper watershed has been proposed.

The largest concentration of steel production in North America is located near the southern tip of Lake Michigan. Five large integrated mills with blast furnaces, and three mini-mills dependent on iron and steel scrap, produce about 25 percent of U.S. steel. The steel industry has had a major impact on land use and the nearshore environment. Its sprawling scale, including fabricating and warehouse facilities, occupies thousands of nearshore acres and unique dune ecosystems. The industry's legacy has generated tons of pollutants, some of which are still present in contaminated sediments in nearshore waters and soil within plant boundaries. Much improvement in air emissions and water effluent has occurred in recent years. For example, water use for process purposes has been substantially reduced with the incorporation of recycling and closed-loop systems.

Orchards are common in the eastern Lake Michigan basin, which is the leading Great Lakes basin source of cherries and apples for processing. The Lake Michigan basin accounts for 45 percent of total Great Lakes basin specialty crop (fruits and vegetables) acreage. Door County, Wisconsin, in the western Lake Michigan basin, is also known for its favorable growing conditions and is an important area for cherry and apple production as well.

The Lake Michigan basin alone accounts for 40 percent of the dairy cows in the entire Great Lakes basin. A well established trend is fewer but larger dairy farms with more milk from each cow. This trend in the dairy industry reflects a larger trend in agriculture towards consolidation and large-scale farming operations. Thus, while there may be a decrease in the actual number of acres used as farmland, those acres are used more intensively than before.

Recreation and tourism are important economic factors in all of the Great Lakes basins; however, due to extensive dunes and beaches, the Lake Michigan basin offers more recreational and tourist opportunities associated with beach activities. The Door County Peninsula is a busy tourist location, with residential vacation developments putting pressure on wetlands, shorelands, and the Niagara Escarpment. Two national lakeshores, Indiana Dunes and Sleeping Bear Dunes, plus many state parks offer recreational opportunities and beach access to thousands of visitors each year.

Low-density sprawl is the predominant development trend in the Lake Michigan basin. Such development has serious implications for the ecosystem, including loss of agricultural land and open space; increased reliance on private automobiles and truck transport and its attendant increased air pollution; high ratio of road surface to development served; increased infrastructure costs; loss of unique character of the landscape; and high land consumption.

Counties in the eastern Lake Michigan basin, for example, experienced reductions in farmland acreage from 7 percent to more than 15 percent from 1982 to 1992, pushing the average for that region well above the average for the state of Michigan during that period (7.8 percent). On the basis of current trends in land value and population growth, the Michigan Society of Planning Officials projects that farms and farmlands in more than two-thirds of the counties in this eastern area are at moderate to high risk due to residential development.

The Grand Rapids area faces the greatest residential pressure in the state, yet it is located within three of the five highest producing agricultural counties (Ottawa, Kent, and Montcalm) in Michigan. Ottawa County, for example, is currently the state leader in agricultural sales. From 1990 to 1995, it also was granted more construction permits (408) under Michigan's Coastal Zone Management Program than any other county in the state. Most of these permits were issued for single family homes and additions to existing homes.

The urban exodus in the extreme southern portion of the basin is also contributing to residential development in the north along the shore. For example, Berrien County, Michigan, adjacent to Indiana, held the second highest number of construction permits on the eastern shoreline between 1990 and 1995.

In the western basin the same trend is apparent. Wisconsin coastal counties on Lake Michigan showed a gain of 41,584 new housing units from 1990 to 1995, nearly half of which were in communities bordering the shoreline. In the land within 305 meters of the Lake Michigan shore, residential land use increased by about 9 percent between 1978 and 1992. Commercial land use in the nearshore area increased by around 17 percent in the same period. Permit applications (rezoning and variance requests) in Wisconsin's coastal counties increased by more than 95 percent between 1992 and 1995. Meanwhile, agricultural and open space lands decreased in 13 out of 15 of Wisconsin's Lake Michigan coastal counties between 1978 and 1992.

Waterfront development has been a major activity in the basin in the 1980s and 1990s, particularly in the urbanized areas of the southern and western portions of the basin. Increased demand for marinas and other water-based recreation opportunities is, in part, the result of improved water quality over the last two decades. Increased environmental awareness is also a factor supporting greater demand for waterfront access and opportunities. Almost all the coastal communities in Wisconsin have had some degree of waterfront revitalization. Also, Indiana's 45 miles of industrialized shoreline is giving way to increased shoreline restoration and preservation efforts as well as marina development. Increased public access and attractively designed waterfront facilities are common to waterfront revitalization efforts. Once old, deteriorated waterfronts are becoming the focal points of communities. Waterfront revitalization is an efficient use of land because it provides new economic and recreational opportunities through the renovation of already developed areas. In contrast, waterfront development along the eastern Lake Michigan shoreline consists primarily of new residences and additions to existing residences, although some redevelopment is underway in more urbanized areas.

G.2.4 Areas of Concern

Areas of Concern (AOC) are severely degraded geographic areas where beneficial uses—activities that are dependent on the chemical, physical, and biological integrity of the water—are threatened or

impaired. Restrictions on fish and wildlife consumption, loss of fish and wildlife habitat, and beach closings are examples of the 14 beneficial use impairments identified under the Water Quality Agreement.

Of the 42 AOCs in the Great Lakes basin, 10 are in the Lake Michigan basin. They are Manistique River, White Lake, Muskegon Lake, and the Kalamazoo River in Michigan; the Grand Calumet River in Indiana; Waukegan River in Illinois; and Milwaukee Estuary, Sheboygan River, Fox River-Southern Green Bay, and Menominee River in Wisconsin. All 14 beneficial uses are impaired at one or more of the AOCs. Remedial Action Plans (RAP) are being developed in each AOC. The Waukegan Harbor AOC is on the road to being delisted. PCB-contaminated sediments have been removed from the harbor, and most of the hazardous waste sites have been cleaned up.

Table G-1. Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Manistique River	- Restriction on fish and wildlife consumption - Degradation of benthos - Restrictions on dredging activities - Beach closings - Loss of fish and wildlife habitat	Water	Heavy metals detected but below levels of concern
		Sediment	PCBs; chromium; copper; lead; heavy metals (zinc, lead, and cadmium); undecomposed sawdust; oil and grease
Lower Menominee River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Beach closings - Loss of fish and wildlife habitat	Water	PAHs; lead, cyanide, chromium, copper, mercury, and phosphorous are detectable but are below levels of concern; arsenic
		Sediment	Arsenic, mercury, PCBs, oil and grease, copper, zinc, lead, cyanide, cadmium, PAHs, and chromium

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Lower Green Bay and Fox River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Beach closings - Degradation of aesthetics - Degradation of phytoplankton and zooplankton populations	Water	Phosphorous and suspended solids, PCBs, ammonia, pesticides, PAHs, and volatile organics
		Sediment	PCBs, PAHs, chlorinated phenols, ammonia, cadmium, mercury, chromium, nickel, copper, zinc, lead, pesticides, oil and grease

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Sheboygan River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Degradation of phytoplankton and zooplankton populations	Water	Phosphorous, heavy metals, PAHs, nitrogen, and suspended solids
		Sediment	PCBs, PAHs, lead, copper, and chromium
Milwaukee Estuary	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Beach closings - Degradation of aesthetics - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	Oil and grease, heavy metals, and dissolved oxygen
		Sediments	Mercury, cadmium, chromium, copper, lead, arsenic, zinc, PCBs, pesticides, PAHs, oil and grease, ammonia, phosphorous, and nitrogen

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Grand Calumet River and Indiana Harbor Ship Canal	- Restriction on fish and wildlife consumption - Tainting of fish and wildlife flavor - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Beach closings - Degradation of aesthetics - Added cost to agriculture or industry - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	PAHs, oil and grease, arsenic, ammonia, chlorides, cyanide, and phosphorous
		Sediments	PCBs, PAHs, phosphorous, nitrogen, iron, magnesium, volatile solids, oil and grease, mercury, cadmium, chromium, lead, naphthalene, benzo(a)pyrene, zinc, and fluoranthene

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Waukegan	- Degradation of benthos - Restrictions on dredging activities - Beach closings - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	Total phosphorous, total ammonia, chloride, sulfates, cyanide, phenols, dissolved oxygen, pH, and total dissolved solids
		Sediment	PCBs, arsenic, barium, cadmium, chromium, copper, cyanide, iron, lead, manganese, nickel, phosphorous, Kjeldahl nitrogen (an estimate of organic nitrogen), chemical oxygen demand, and volatile solids
Kalamazoo River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Beach closings - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	PCBs and nonpoint source pollution (urban)
		Sediment	PCBs
Muskegon Lake	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	Phosphorous, un-ionized ammonia, dissolved oxygen, pH, and total dissolved solids at levels below concern; heavy metals, oil and grease, phosphorous, and nitrogen of concern in localized areas
		Sediment	PCBs, mercury, lead and arsenic, cadmium, chromium, copper, nickel, and zinc

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
White Lake	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	Phosphorous, heavy metals, chloride, and nitrogen
		Sediment	Chromium, lead, arsenic, cadmium, manganese, mercury, nickel, zinc, PCBs, oil and grease

(Source: Lake Michigan Forum. 1996. Lake Michigan Areas of Concern. 1999. http://www.lkmichiganforum.org/areasofconcern.html)

G.2.5 Areas of Stewardship

Areas of Stewardship are broad landscape areas or nearshore aquatic areas with the following:

- Concentrations of species of special interest such as the endangered prairie white-fringed orchid, a lakeplain prairie species
- Outstanding examples of special communities, such as the coastal wetlands of the western shore of Green Bay
- Excellent representations of landforms or typical vegetation and wildlife communities, such as the Niagara Escarpment in Door County and the Garden Peninsula
- Exceptional levels of natural diversity, including both habitat and species diversity, such as the southern end of the lake with dunes, prairies, savannas, and wetlands and more than 350 species of plants alone
- High levels of ecological connectivity, such as the Crystal River, Michigan, watershed

During the 1996 State of the Lakes Ecosystem Conference (SOLEC), nearshore terrestrial Biodiversity Investment Areas were identified throughout the Great Lakes basin. Four Biodiversity Investment Areas within the Lake Michigan basin were identified: Michigan Islands, Chicago Wilderness, Door County Peninsula, and Green Bay Western Shore. At the regional Lake Michigan basin scale, additional smaller coastal areas and inland areas can be added to the four large-scale, nearshore areas: Seney Wildlife Refuge, Wilderness State Park, Grand Traverse Bay, Sleeping Bear Dunes, Allegan State Game Reserve, and Menominee Tribe Reservation.

Coastal wetland and nearshore aquatic Biodiversity Investment Areas were also identified for SOLEC 1998. Additional work needs to be done to characterize proposed areas and to understand the relationship of people to these sites.

Designating areas as Biodiversity Investment Areas or Areas of Stewardship does not mean there are no other significant areas of biodiversity in the Lake Michigan basin. In fact, numerous other high quality,

but smaller, such areas exist. From a Lake Michigan basin perspective, however, the emphasis in these areas is their clusters of biodiversity values that warrant special attention.

Areas of Stewardship are not necessarily pristine. Several, such as the Michigan Islands, have very little disturbance to their natural features and processes, but others, such as Chicago Wilderness, have been substantially altered from their original state, yet retain remnant natural areas and ecological values of exceptional significance.

G.3 KEY LAKE MICHIGAN HABITAT TYPES AND AREAS

Section 4.2 of this document describes and assesses the major habitats in the Lake Michigan basin. The following section provides an overview of selected key areas within these Lake Michigan habitats.

G.3.1 Coastal Marshes System

Green Bay Western and Northern Shores

Green Bay's western and northern shores have low sand banks fronted with low beach ridges and numerous fringe wetlands. Huge bulrush beds flank the shore in Big and Little Bay de Noc and other protected bays. Behind the active beach barrier, inactive beach ridges may exist, which in turn flank large lagoons and interior marshes of cattails, open water, sedge meadows, and shrub zones. Some of the finest examples of Great Lakes marshes are in northern Green Bay and along the eastern side of the Door Peninsula.

Door Peninsula

The Door Peninsula has 4.2 percent of all of Wisconsin's Great Lakes coastal marshes. Of these, most are ridge and swale complexes that run parallel to the lake. The Mink River estuary, Ridges Sanctuary, Mud Lake State Wildlife Area, and other reserves offer a diversity of plants and habitat for wetland birds (Scheberle 1999).

Eastern Lake Michigan

There are no littoral marshes along the eastern shore of Lake Michigan, but there are some extensive interdunal wetlands between the dune ridges, small intradunal wetlands in depressions within the dunes, and considerable wetlands tucked into and up every tributary. These are large "drowned river mouth" marshes that formed as lake levels rose from a lower previous level. Some are very extensive and all have been severely modified in their lower reaches due to marina and condominium development, housing, and other commercial enterprises.

The Grand River Estuaries in Ottawa County are a complex of estuarine marshes of high quality. It is an example of a Great Lakes Estuary Marsh community, which is globally imperiled. Because it is located at the intersection of the Atlantic and Upper Mississippi Flyways, these river marshes are important feeding areas and a migration corridor for waterfowl such as Canvasback, Lesser Scaup, Redhead, Goldeneye, and Bufflehead diving ducks, and dabbling ducks such as Mallard, Black duck, Baldpate, Pintail, and Blue-winged teal. Osprey forage in the marshes (The Nature Conservancy 1995).

A typical marsh system in this area is found in the Betsie River. A narrow, short channel separates Betsie Lake from Lake Michigan. The dune fields are thus interrupted by the river valley, and Betsie Lake has had most its shoreline wetlands eliminated by bulkheads or shore maintenance. Betsie Lake then narrows in its upper reaches and merges within the Betsie River and its associated floodplain. Large tracts of

floodplain wetlands then characterize the river for many kilometers, becoming narrower upstream. As the water levels of Lake Michigan trend higher in some years, the wetlands near the channel recede to the floodplain and shore terraces because the water near the channel becomes too deep. When levels are low, mudflats often become exposed, quickly being colonized by new hydrophytes, and the wetlands expand to the channel margins. Thus, the diversity of the wetland vegetation is greatly enhanced by the natural fluctuations of the lake level.

North of Leland, through the Traverse Bays, and continuing north to the Straits of Mackinac, the shore of Lake Michigan changes again into rocky cliffs and bluffs, cobble beaches, and occasional embayed wetlands of small size. The high relief shores preclude any opportunity for lakeplain wetland development, and the actual shoreline is under constant wave attack from deep water. Along the offshore islands (such as Manitou, Fox, and Beaver) the situation is similar, although a few do exist as lagoon wetlands protected from Lake Michigan.

Northern Lake Michigan

From the Straits of Mackinac westerly, the Michigan shore becomes distinct again, with low relief, multiple sand ridges being interrupted by shallow, sheltered bays. Many of these bays have large shoreline wetlands that intergrade into beach swales, wet meadows, and shrub thickets before the more upland plants become apparent. All along this stretch, the forest dune and swale complex is well developed, leftover from ancient higher lake levels (Minc 1998). Where the major rivers or small creeks empty, riverine and lagoon wetlands flourish upstream, with good examples at practically every outlet. Along the Garden Peninsula, many embayed wetlands remain untouched, fronting on low relief uplands or tucked between large limestone cliffs.

Greater Calumet Wetlands

On the southern shore of Lake Michigan in Cook County, Illinois, and Lake County, Indiana, are the remnants of a formerly huge lake-related wetland complex called the Great Calumet wetlands. Embedded in a now urbanized and industrial setting on about 1,000 acres, Panne, Pond, Marsh, Wet Prairie, Sedge Meadow, and Shrub Swamp communities that lie among the old lakeplain ridges still support a rich diversity of boreal, Atlantic coastal plain, and Great Plains prairie species. The Interdunal Wetland community type is globally rare. More than 700 plant species, 200 birds, 14 mammals, 21 reptiles and amphibians, 22 fish, 29 macroinvertebrates, and 15 butterflies, many rare and endangered, have been recorded in the Greater Calumet Wetlands recently. Notable species are the Black-Crowned Night Heron *(Nycticorax nycticorax)*, the Least Bittern *(Ixobrychus exilis)*, and the Blandings Turtle *(Emydoidea blandingii)*. This area is a major stopover point for migratory birds (The Nature Conservancy 1995).

G.3.2 Inland Wetlands System

Seney Wildlife Refuge, Michigan

Seney Wildlife Refuge was part of the Great Manistique Swamp. This wilderness area contains many bogs interspersed among hardwood, spruce, fir, and tamarack forests. Over 25,000 acres, this refuge is home to many species of ducks, bald eagles, osprey, loons, trumpeter swans, otter, beaver, black bear, moose, and wolves. It is an important breeding and resting place for migratory birds (U.S. Fish and Wildlife Service 2000).

Turner Creek Wetlands, Michigan

At the headwaters of Turner Creek is a complex of Wet Prairie, Prairie Fen, Southern Wet Prairie, and Conifer Swamps. The area lies within the Barry State Game Area and may be a source site for rare fen plant species in the area. The globally imperiled Mitchell's Satyr butterfly *(Neonympha mitchellii)* is found here (The Nature Conservancy 1995).

Allegan State Game Area Marshes, Michigan

The Allegan Marshes are recognized as the least disturbed remaining complex of globally imperiled Inland Coastal Plain Marsh community in North America. The marshes were shaped by glacial runoff and differ in size, water depth, and amount of peat accumulation; therefore, plant species vary. Many of the plants are globally imperiled, including Hall's Bullrush *(Scirpus hallii)* (The Nature Conservancy 1995).

Mill Creek Wetlands, Michigan

The headwaters of Mill Creek in Cass and St. Joseph Counties is a complex of southern wet meadow, shrub swamp, and conifer swamp. Springs along the creek create fen habitat. The area is within the Three Rivers State Game Area and is home to rare and threatened species, including the globally imperiled Michell's satyr butterfly *(Neonympha mitchellii)*, Copperbelly water snake *(Nerodia erythrogaster neglecta),* and Eastern Massasauga snake *(Sistrurus catenatus catenatus)* (The Nature Conservancy 1995).

Pinhook Bog, Indiana

Pinhook Bog, part of the Indiana Dunes National Lakeshore, was formed when a large chunk of glacial ice melted, leaving a kettle hole lake. This bog is an example of a quaking kettle-hole bog and one of the few remaining in Indiana. The northern carniverous pitcher plant and the sphagnum moss are common plants that live on the thick peat mat. The deciduous tamarack tree, pink lady's slipper orchids, and yellow fringed orchids are found in the preserve (Indiana Dunes National Lakeshore 1992).

Cherry Lake Sedge Meadow, Wisconsin

Cherry Lake Sedge Meadow is located in a serpentine basin in glacial till. With only a few openings in the deep sedge mat, Cherry Lake is a misnomer. The sedge meadow contains both alkaline- and acid-loving plants. Of special interest are round-leaved sundew, shrubby cinquefoil, yellow twayblade, marsh St. Johns wort, marsh fern, and sphagnum. To the north of the sedge meadow is a small fen. Shrub-carr is scattered throughout the area, and a tamarack-poison sumac bog lies to the northeast. There has been some tamarack die-off, which promotes even more bushy growth. A portion of an esker runs along the west boundary. This upland area has been grazed in the past and is now brushy oldfield.

G.3.3 Tributary Systems

Manistique River, Michigan

The Manistique River flows southwest through Michigan's central Upper Peninsula. It has been identified as an AOC because the last 1.7 miles of the river, from the dam to the mouth of the harbor at Lake Michigan, have been significantly altered. Historical uses of Manistique River waters in the AOC include receiving wastes from sawmills, a paper mill, small industries, the municipal wastewater treatment plant, plus navigation for shipping, ferrying, recreational boating, and commercial fishing.

Current uses include receiving the wastewater discharges from municipal and industrial dischargers (Lake Michigan Forum 2000).

Grand Traverse Bay, Michigan

The Grand Traverse Bay watershed in Michigan is huge, consisting of more than 20 tributaries and 100 inland lakes in a 1,000-square mile area.

Manistee River, Michigan

The Lower Manistee River is a slow and wide river that meanders through rolling hills and rich marsh land. It is a good salmon fishing river.

Pere Marquette River, Michigan

The Pere Marquette, designated a Wild and Scenic River, is characterized by overhanging bluffs and grassy floodplains. It supports fine trout habitat.

Grand River, Michigan

The Grand River is the longest river in the Lake Michigan basin at 262 miles. It flows through Michigan's agricultural and orchard region. It is now becoming an area of development all the way to the lake. A new watershed group has been formed to deal with issues and problems of water quality.

Kalamazoo River, Michigan

The Kalamazoo River has been identified as a Great Lakes AOC due to historic releases of PCBs from de-inking operations at local paper mills (Lake Michigan Forum 2000).

Grand Calumet River, Indiana

The Grand Calumet River is approximately 16 miles long and has a basin area of about 62 square miles. Extending across the Indiana-Illinois border, it lies to the south of Lake Michigan in Northwest Indiana. Originally the river drained into Lake Michigan at mouths on both its western and eastern ends. A harbor built in the 1870s permitted water to flow westward more easily. The eastern mouth of the river receded into a lagoon at what is now Marquette Park in Gary. Inland Steel Company financed the construction of the Indiana Harbor Ship Canal in the early part of the twentieth century. Today, the river is considered one of the most polluted in the country, much of the original vegetation has been replaced by nonindigenous species, and sediments are contaminated. Remediation efforts are underway (Grand Calumet Task Force 2000).

Chicago River, Illinois

The Chicago River is an urban waterway much altered from its original state. Heavy industry and urban buildup forced the reversal of the river flow towards the Mississippi River and away from Lake Michigan early in the 20th century. Today, although still tremendously affected by urbanization, movement to restore the river and improve water quality are underway (Wallin 1995).

Milwaukee River and Swamp State Natural Area, Wisconsin

The east branch of the Milwaukee River is a slow, meandering warm water stream with a population of northern pike, black crappie, walleye, and other species. A spring feeds the river in the north. Adjacent to the river is a shrub zone, a lowland hardwood forest, a conifer swamp, and a small bog lake. This portion of the river is a natural area of some importance (Wisconsin Department of Natural Resources 2000). The lower part of the Milwaukee River, however, is an AOC with 11 of 14 beneficial uses impaired. Fish and waterfowl are contaminated and unfit for consumption. Species diversity is low, and habitats are impaired due to contamination and hardened shores (Lake Michigan Forum 2000).

Sheboygan River, Wisconsin

The lower Sheboygan River is an AOC. It is a sink for pollutants from three watersheds: the Sheboygan River, Mullet River, and Onion River watersheds. The area is lined with residential, industrial, and municipal development, with agriculture being the predominant land use at 67 percent (Lake Michigan Forum 2000).

Fox-Wolf Rivers, Wisconsin

The Fox-Wolf Basin in northeast Wisconsin drains 6,400 square miles before flowing into Lake Michigan at Green Bay. The fish, wildlife, benthic populations, and habitat of this watershed are degraded, primarily as a result of a variety of industries. Over the last three decades, while the health of the river has improved significantly, many important water resource issues remain. Walleye from the river, for example, is not safe to eat because of persistent toxic chemicals such as PCBs, mercury, and more than 100 other substances. The waters receive loads of soils and nutrients washed into hundreds of miles of streams and tributaries from lawns, streets, parking lots and agricultural fields. Exotic species are present. The Lake Winnebago pool lakes and the lower bay of Green Bay continue to experience algae blooms, inhibiting recreational use. This area was listed as a Great Lakes AOC by the International Joint Commission (Lake Michigan Forum 2000).

Wolf River, Wisconsin

The Wolf River originates north of Mole Lake Reservation in northeastern Wisconsin. In the upper part of the river, it is characterized by high granite walls, cascades, rapids, and waterfalls. It is considered a world-class whitewater rafting destination. In 1968, part of the river was designated as a National Wild and Scenic River. The river's water quality and fishery is the best in the Lake Michigan basin. Wisconsin has designated the river an Outstanding Resource Water. The Wolf is one of the premier brown, brook, and rainbow trout fishing rivers in the region. The Bald Eagle, Osprey, and other bird species nest and feed along the river. The Menominee and Chippewa Tribes have deep spiritual and culture connections to the river, which supports abundant wild rice beds and habitat for lake sturgeon (Menominee Tribe 2000).

G.3.4 Coastal Shore System Dunes

Wilderness Point State Park, Michigan

Wilderness Point State Park lies in the northernmost part of Michigan's lower peninsula. Low dunes and interdunal wetland communities are nesting habitat for the federal and state-endangered piping plover and other shorebirds. Several Great Lakes endemic dune species, including the Pitcher's thistle, Houghton's goldenrod, and the Lake Huron tansey are found here, along with a diversity of other hardy

plants. This is a remote and wild park that offers passive recreational opportunities (Michigan Department of Natural Resources 2000).

Sleeping Bear Dunes National Lakeshore, Michigan

The highest dunes on the Lake Michigan shoreline are found at Sleeping Bear Dunes National Lakeshore. The dunes rise as high as 460 feet above the lake. Along the shore are beach dunes, and on plateaus above the shore are perched dunes. Constant exposure to wind, ice, and water keeps the dunes moving. Beachgrass and sand cherry are among the first dune colonizers. Inland are lakes and streams as well as beech-maple forests (National Park Service 2000).

Ludington Dunes, Nordhouse Dunes, Michigan

Combined, Ludington and Nordhouse Dunes are called Big Sable Dunes and are the largest freshwater expanse of dunes in North America. In addition to a healthy population of the Great Lake's endemic pitcher's thistle, the dunes have a rich variety of species in interdunal wetland habitats. Inland from the foredunes are older dune ridges with mature second-growth beech, maple, and oak forests (Michigan Department of Natural Resources 2000).

J.P. Hoffmaster State Park Wild Area, Michigan

The dunes at J.P. Hoffmaster State Park Wild Area cover more than 1 mile of the Lake Michigan shoreline. The high dunes contain large blowouts. Inland, the dune ridges are comprised of mature beech, maple, hemlock, oak, and black cherry trees (Michigan Department of Natural Resources 2000).

Saugatuck Dunes Natural Area, Michigan

Diverse dune and interdunal wetland communities are found at Saugatuck Dunes Natural Area. This relatively undisturbed site has nesting habitat for the federal and state endangered piping plover. Healthy populations of Great Lakes endemics Pitcher's thistle, Lake Huron tansy, and Houghton's goldenrod are found here (Michigan Department of Natural Resources 2000).

Grand Mere Natural National Landmark, Michigan

Grand Mere Natural National Landmark contains high-relief dunes formed more than 10,000 years ago. The inland lakes and interdunal wetlands at this site are unique in the region. Ecological community types range from aquatic to forest. This is a significant songbird and waterfowl migration area (Michigan Department of Natural Resources 2000)

Warren Dunes State Park, Michigan

Warren Dunes State Park includes stabilized dune ridges inland and active dunes close to Lake Michigan. Geologically, this is an unusual site because the dune ridges enclose smaller and interlocking dune ridges that are different ages. The site has large blowouts and habitat for a diversity of plants and animals. In the spring, the wooded, inland dunes are rich with woodland wildflowers (Michigan Department of Natural Resources 2000).

Indiana Dunes National Lakeshore and State Parks

The dunes along the 40-mile stretch of Lake Michigan shoreline from Michigan City to Gary, Indiana, are protected in the Indiana Dunes National Lakeshore and State Parks. Several live or moving dunes, including tall Mt. Baldy, constantly shift with the wind. Marram grass and cottonwood trees are the first dune colonizers along with populations of the rare Pitcher's thistle. The dune ridges are a unique blend of boreal plants such as arctic bearberry, southern dogwoods, northern jack pines, and prickly pear cactus. The beaches are wide in low lake-level years, and the sand is often called "singing sands" due to the sound made when it is walked on. Professor Henry Chandler Cowles studied the dunes here in the late 1800s and developed the principles of plant succession that are basic to the evolving history of ecology today (National Park Service 2000).

Kohler Park Dunes, Wisconsin

Kohler Park Dunes has 1 mile of sand beach and small, active, and stabilized sand dunes. Inland, from the dunes lies a dry, white pine forest. Interdunal pannes or wetlands contain rushes and sedges. Dune plants found here include sand reed, Canada wild rye, marram grass, northern wheat grass, junipers, sand cherry, and willows. This is a fall migration route for raptors (Wisconsin Department of Natural Resources 2000).

Wilderness Ridge, Wisconsin

Wilderness Ridge was formed when a rapid lake level fall exposed the sand ridges. Today these dune ridges are mature and vegetated with red and white pines, hemlock, sugar maple, red maple, and yellow birch, and a groundlayer of bluebead lily, wintergreen, starflower, Canada mayflower, goldthread, and trailing arbutus. Another part of the ridge contains several sedge meadows with 28 species of sedges and a variety of grasses (Wisconsin Department of Natural Resources 2000).

Whitefish Dunes State Natural Area, Wisconsin

Whitefish Dunes State Natural Area contains both sand beaches and active and stabilized sand dunes. The inland dunes are forests of sugar maple, American beech, white cedar, balsam fir, and hemlock. A small lake with a sedge meadow and a baymouth bar lake are on site as well. The site is rich in plant species including Canada yew. Red-eyed vireo, veery, black-throated green and Canada warblers, American redstart, and eastern wood pewee nest here (Wisconsin Department of Natural Resources 2000).

Jackson Harbor Ridges State Natural Area, Wisconsin

Behind the beach and low sand ridges at Jackson Harbor Ridges State Natural Area are interdunal calcareous wetlands. These wetlands contain many rare plants, including Kalm's lobelia, shrubby cinquefoil, arctic primrose, low calamint, slender bog arrow-grass, and bladderworts. Secondary dunes are vegetated with the boreal bearberry, horizontal juniper, and sand coreopsis. Inland dunes are a mix of conifer-hardwood forest of red and white pines, white cedar, balsam fir, and American beech. At the entrance to Jackson Harbor is a sand spit that attracts gulls, terns, shorebirds, and other waterfowl (Wisconsin Department of Natural Resources 2000).

Ridges Sanctuary, Wisconsin

The Ridges Sanctuary is a series of Lake Michigan sand dunes or ridges forested with black spruce, white spruce, balsam fir, and white pine. Wet swales lie between the ridges. Swamp conifers and marsh

and bog plants are in the swales. Some of the ridges are wet and calcareous. The forest has boreal components, a disjunct from the boreal forest found on Lake Superior (Wisconsin Department of Natural Resources 2000).

G.3.5 Coastal Shore System Beaches

Illinois Beach State Park, Illinois

Just north of Chicago and the northern suburbs, Illinois Beach State Park's 6.5 miles of shoreline is the only beach ridge shoreline left in the state. The park has more than 650 species of plants, including prickly pear cactus, grasses, sedges, and wildflowers. Away from the wide beaches are low dunes followed by sandy ridges with black oak woodlands. The Dead River opens into the lake and is surrounded by interdunal ponds rich in aquatic life (Illinois Department of Natural Resources no date).

Bedrock Shore

The northern shoreline of Lake Michigan is characterized by rugged limestone and dolomite bedrock concentrated in the Garden Peninsula. Part of the Niagara Cuesta, the deposits are more than 400 million years old, deposited as reefs constructed of marine organisms (Albert 1997). Bedrock shores are shaped by wave and ice erosion. Cracks in the rocks contain plant life, and seasonal pools form in low areas carved into the rock.

Cobble beaches are common along rocky shorelines. Cobbles are rock chunks made up of limestone. Little vegetation is present due to exposure to severe wave and ice action. Lichens and mosses are most common because they grow even under harsh weather conditions. Although there is a possibility unique animals may inhabit bedrock shores, little is known about the fauna of this community. Additional research is needed to inventory animals.

In addition, an increase in second home development along the northern shore may soon impact bedrock shore areas.

G.3.6 Lakeplain System Prairies

Hoosier Prairie, Indiana

Hoosier Prairie is a tallgrass prairie remnant, one of few remaining black soil prairies in Indiana. Hundreds of plant species, such as big bluestem grass, bush clover, and rough blazing star, are found in a diversity of habitats ranging from mesic prairie to oak savanna to prairie marsh. The prairie is a registered National Natural Landmark (Indiana Department of Natural Resources No Date)

Somme Prairie Nature Preserve, Illinois

Hundreds of flowers bloom throughout spring, summer, and fall in Somme Prairie Nature Preserve, a small tallgrass prairie remnant. Flowers include hoary puccoon *(Lithospermum canescens)*, rattlesnake master *(Eryngium yuccifolium)*, wild quinine *(Parthenium integrifolium)*, and prairie dock *(Silphium terebinthinaceum)*. Skipper butterfly caterpillars feed on the grasses and sedges, and orange and black fritillaries feed on the violets. The preserve has an abundance of snakes, salamanders, and birds such as meadowlarks (Chicago Wilderness No Date).

Chiwaukee Prairie, Wisconsin

Once connected to no longer present coastal marshes and the lake itself, this preserve still maintains a diverse population of plants and butterflies. In the spring it is not unusual to see thousands of pink shooting stars blooming. Management is focused on eradicating exotic invasive species and using prescribed burns to control brush.

G.3.7 Lakeplain System Oak Savannas

Allegan Pine Plains, Michigan

The Allegan Pine Plains is a black oak savanna and prairie with vegetation that includes little blue-stem grass, Pennsylvania sedge, bird's-foot violet, ragwort, wild lupine, hairy puccoon, and dwarf blazing star. The landscape is adapted to fire, and prescribed burning is used to manage this natural community (Michigan Department of Natural Resources 2000).

Miller Woods, Indiana

Miller Woods is a black oak savanna in the westernmost part of the Indiana Dunes National Lakeshore. It is set in the middle of U.S. Steel, the City of Gary, and Lake Michigan. It is dune and swale topography shaped about 3,000 years ago. Between ridges lie richly vegetated interdunal ponds. The flora of Miller Woods is significant because its pre-European settlement integrity has been maintained. Miller Woods also has numerous bird residents such as the Red-Headed Woodpecker, as well as a population of the federally endangered Karner blue butterfly (Peloquin No Date).

Middle Fork Savanna, Illinois

Middle Fork Savanna in Lake County, Illinois, is an outstanding example of an oak savanna community. It has much of the understory diversity original to the area. It is now under management by the Lake County Forest Preserve District. Controlled burns have been reintroduced, and invasive species such as garlic mustard, honeysuckle, and European buckthorn are being eliminated (De Vore 1997).

G.3.8 Lakeplain System Sand Barrens

Shakey Lakes, Michigan

Shakey Lakes is the largest area of pine and oak barrens in northern Michigan. Five savanna ecosystems are found at the site. Before European settlement, the savanna was maintained by native peoples who set fires on a regular basis to improve habitat for game and shrubs such as blueberries (Michigan Department of Natural Resources 2000).

Dunbar Barrens State Natural Area, Wisconsin

Dunbar Barrens State Natural Area is a pine barrens located on an outwash plain. This gentle topography is forested with jack pine, aspen, and oak. Grasses, sedges, and shrubs dominate the groundlayer. Other plants include rice grass, poverty oat grass, bearberry, blueberries, sweet fern, barrens strawberry, and hawkweeds. Lichen is also present and diverse. Common barrens birds found here include Upland Sandpiper, Eastern Bluebird, Rufous-sided Towhee, Vesper Sparrow, Field Sparrow, and Clay-colored Sparrow (Wisconsin Department of Natural Resources 2000).

G.3.9 Inland Terrestrial Systems

Warren Woods, Michigan

Warren Woods is a 179-acre virgin beech-maple forest, the last of its type known in Michigan. Tree species are diverse and large, with some more than 5 feet in diameter and 125 feet in height. The understory has a profusion of spring wildflowers (Michigan Department of Natural Resources 2000).

Lulu Lake, Wisconsin

Lulu Lake is a 95-acre, 40-foot deep, hardwater drainage lake in southeastern Wisconsin. A small bog is surrounded by tamarack forest and northern bog species. An inlet stream is banked by a richly vegetated sedge meadow and a fen. The uplands are glacial moraine covered with oak forest and oak openings dominated by bur, white, and red oaks (Wisconsin Department of Natural Resources 2000).

Kewaskum Maple-Oak Woods State Natural Area, Wisconsin

Located east of the Milwaukee River, Kewaskum Woods is a sugar maple, red oak, white ash, and basswood forest. The rich groundlayer contains uncommon woodland species, including orchids, golden seal, large-fruited snakeroot, broad-leaved puccoon, dog violet, and smooth bank cress. Common nesting birds include Black-billed and Yellow-billed Cuckoos, Great-crested Flycatcher, Eastern Wood Pewee, Wood Thrush, Blue-gray Gnatcatcher, Red-eyed Vireo, and Scarlet Tanager (Wisconsin Department of Natural Resources 2000).

Toft Point State Natural Area, Wisconsin

Toft Point State Natural Area contains a narrow strip of relict boreal forest dominated by balsam fir and white spruce. The peninsula also includes a forest of sugar maple, yellow birch, hemlock, and scattered white pine. Along Moonlight Bay lies an extensive sedge meadow. A wet-mesic forest is dominated by white cedar with occasional paper birch and black ash. Seventeen species of nesting warblers are found at the site (Wisconsin Department of Natural Resources 2000).

Miscauno Cedar Swamp State Natural Area, Wisconsin

Miscauno Cedar Swamp is a conifer forest of white cedar, balsam fir, and black spruce. Black ash and elm are found along Cedar Creek. Tamarack snags indicate this tree was historically present. Orchids, bunchberry, starflower, bluebead lily, gaywings, Canada mayflower, and several fern species are found in the ground layer. Mosses and lichens are found in headwater springs. Breeding birds include the Raven, Hermit Thrush, Black and White Warbler, Pine Warbler, Scarlet Tanager, and Black-billed Cuckoo (Wisconsin Department of Natural Resources 2000).

Menominee Reservation

The Menominee Reservation is located at the tension zone that divides the northern and southern forests. Therefore, it contains a diversity of tree species not found elsewhere. The dominant forest types are northern hardwoods; hemlock hardwoods; jack, red, and white pines; aspen; scrub oak; and swamp forest. More than 2.5 billion board feet of lumber have been harvested here in the past 150 years. The volume of standing timber today, however, is greater than when the Wolf River Treaty defined the reservation in 1854. Sustained yield forestry is the management used. The Menominee Tribal

Enterprises is a company with a Menominee forest-based sustainable development tradition that is widely recognized as a leader in sustainable forest management (Menominee Indian Tribe of Wisconsin 1997).